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SEA ISLAND COTTON INDUSTRY.*

THE report of the fifth general ordinary meeting of the West Indian Sea Island Cotton Association which was held last November in Antigua has just been issued. Sir Frank Stockdale, Comptroller for Development and Welfare in the West Indies, and Mr. A. J. Wakefield, Inspector General of Agriculture for the West Indies, were present. Brief reference will be made here to the more important matters considered in connection with the industry.

Sea Island Cotton during the past season has been grown under generally favourable conditions and, with a marked increase in the area under cultivation in Antigua, Nevis and Montserrat a record crop of 7,791 bales was produced. The industry has been most fortunate also in that there has been a demand for Sea Island Cotton to be used for a special purpose in the war effort. In consequence it has been possible to dispose of the entire crop, and quite recently a contract has been made between the growers and the Ministry of Supply of His Majesty's Government for the disposal of the crop under what may be regarded as distinctly favourable terms. The Ministry has agreed to purchase all West Indian Sea Island Cotton produced during the period of the war and planted before the general cessation of hostilities at an f.o.b. price of 25 pence per pound of clean lint for the superfine strain cotton grown in St. Vincent, and 22.5 pence per pound for the Montserrat strain of cotton now grown in all the Leeward Islands. With this contract in hand the industry should for the present be able to continue on a reasonable basis. Future production, however, will have to be watched closely to ensure that expansion of cotton cultivation does not take place at the expense of food production or under conditions which favour soil erosion.

Sir Frank Stockdale in an address to the meeting pointed out that the sole demand for Sea Island Cotton today was for defence purposes and that the position may arise after the war when there may be little or no demand for Sea Island Cotton. Producers were urged, therefore, to give serious consideration to the possibility of setting

* Report of the Fifth Ordinary General Meeting of the West Indian Sea Island Cotton Association (Incorporated) held in Antigua, November, 1940. Price: 2 shillings. May be obtained on application to the Editor of *Tropical Agriculture*.

substantial funds aside for propaganda and advertisement purposes after the war. As Sea Island goods are the ideal goods for tropical wear Sir Frank thought that such propaganda should not be limited solely to the United Kingdom but also be actively undertaken in the West Indies and carried even further into India and the tropics of the East. He felt that it was only by such means that the difficulties which are going to come to this industry at the end of this war can be faced and urged that as big a sum as possible should be built up for propaganda purposes for the post-war period.

The meeting discussed a memorandum prepared by Mr. J. B. Hutchinson, Cotton Adviser, containing a summary of information on the yield of Sea Island varieties. The Chairman stressed the importance of conducting further trials and advised that the respective Island Associations take the necessary steps to ensure that all possible facilities are placed at the disposal of the local agricultural departments for conducting such trials.

A resolution on the subject of renaming the strains of West Indian Sea Island Cotton by the Nevis Cotton Growers Association was read. The Chairman referred the meeting to the minute on this subject recorded at the fourth ordinary general meeting and reported that the Advisory Committee advised that the opinion of the trade in this matter should be followed. The views of the trade were that brokers have always been in the habit of naming the cotton according to the island in which it is grown because in their opinion cotton from every island in the West Indies differs in characteristics from whatever seed it is grown probably due to different climate and soil; and that buyers judge the cotton entirely on its merits after their own examination, quite irrespective of the strain from which it is grown. After discussion the meeting decided to accept the advice of the Advisory Committee and agreed that, in the circumstances, no system of re-naming the strains should be introduced for the present, but requested the President to undertake further enquiries in consultation with the Cotton Adviser and report to the Association.

The meeting reviewed and compared the measures adopted for controlling cotton pests during the past season in the various islands. The Chairman urged that Island Associations should take an active interest in the measures adopted for pest control and that, where necessary, they should take steps to ensure that adequate stocks of insecticides and spraying equipment are maintained.

Discussion took place on the subject of spraying equipment and it was decided that funds should be made available to the President to investigate and determine types of sprayers of British manufacture suitable for use under the conditions of the West Indian cotton industry. The condition of cotton ginneries in relation to pink bollworm control was also discussed.

SWOLLEN-SHOOT DISEASE OF CACAO.

As research on Swollen-shoot disease of cacao has led to certain definite conclusions, we are publishing in this issue an account of this work which we hope will be welcomed by cacao investigators in other countries. In this article, Mr. Posnette records early diagnosis of the disease, negative results for inoculation, transmission by budding and by seed, negative results for transmission by several insects and positive results for transmission by the cacao Psyllid. This research is being followed up, especially as regards the insect vector or vectors.

There seems to be no doubt that Swollen-shoot must rank as one of the most serious diseases of cacao now known. The map accompanying the article shows the known areas of infection. It will be seen that the main centre of infection, some 250 to 400 square miles, is in a portion of the Eastern area of the Gold Coast Colony with scattered outbreaks to the North East and Westwards towards the Ashanti border.

In the main centre of infection direct control measures are by now impracticable and the most urgent problem is therefore to prevent, or at least to delay, the spread of Swollen-shoot to Ashanti and to the uninfected districts in the Colony. This will be accomplished, it is hoped, by the treatment of scattered outbreaks working from the furthest inwards towards the main centre of infection, by the establishment of cacao-free belts around the infected areas making much use of the forest reserves and accompanied by systematic patrols for the disease in the scattered outbreak areas and beyond, and by tracing and prohibiting the transport of cacao seed and plants from infected areas. The treatment of a scattered outbreak consists of spraying with an insecticide a radius round an infected area, stumping all infected trees and a ring of apparently healthy trees immediately surrounding them, and again spraying the same area.

These measures should confine the virus but the greatest need is resistant planting material. An extensive cacao selection programme has been launched which is aimed at the propagation of resistant strains. In some farms killed by the virus, one or two trees have remained healthy and it is hoped that these will prove to be immune or highly resistant, but it is hoped that allied species and Imperial College selections of cacao will also be examined for resistance.

SWOLLEN-SHOOT VIRUS DISEASE OF CACAO.

(Review of Research work to November 1940)

By A. F. Posnette.
(Department of Agriculture, Gold Coast.)

History.

Extensive die-back has been reported from the Nankese district since 1930. Swollen-shoot was not found in this locality until after it had been discovered at Effiduase in 1936, but subsequent evidence points to the conclusion that most probably the disease was present at Nankese in 1930, if not much earlier.

Steven (1) was the first Mycologist to investigate the disease, his description appearing in November 1936. Although he isolated no pathogen likely to be a primary parasite, his field observations led him to conclude that Swollen-shoot was infectious. Consequently, a cutting out campaign was started, in the course of which about 300 farms were treated and over 81,000 trees destroyed. It soon became apparent that the disease was more widespread than had been anticipated. Failure to recognise the early symptoms meant that many fresh cases were found when farms were inspected a few months after treatment.

Wright (2), Deighton (3) and Dade (4) also failed to isolate a primary parasite, and Dade concluded that "the evidence points to a physiological and not to a parasitic diagnosis", the main trouble being due to poor environmental conditions obtaining in the affected area.* The sanitation campaign was therefore terminated in 1937 and attention given to reducing drought die-back by a policy of shade tree planting (5).

Greenwood (6) made an investigation of the soils of the Nankese area in 1934. He concluded "that analysis reveals no significant difference in nutrient status between soil from good cacao, and from dead and dying trees. No simple toxic effect, or soil deficiency, has been discovered". In 1940, after examining soils from other infected areas, he stated that "routine methods of analysis show no difference in inherent fertility between adjacent patches of healthy and diseased cacao. The subsequent spread of Swollen-shoot to some of the areas here described as healthy strengthens this conclusion".

Working in collaboration with E. F. S. Shepherd, Plant Pathologist, the writer started field observations in 1938; these soon indicated that the disease spreads irrespective of environmental conditions, a conclusion now amply confirmed.

* For maps of the area, with rainfall figures, *see* "Cacao Die-back" by Voelcker and West, *Trop. Agriculture* XVII, No. 2 and back covers of *G. C. Farmer*, VI, Nos. 1, 2 and 4.

Transmission Experiments.

(*a*) Inoculation.

Shepherd (7) carried out numerous inoculation experiments with a strain of bacteria cultured from swollen tissues; also with extracts of crushed swollen tissue. In none of these did transmission occur. An experiment involving the application of growth-promoting chemicals (Phenyl-propionic and Indolyl-propionic acids) to the soil also gave negative results.

(*b*) Budding.

Preliminary experiments were made on transmission by budding, and gave the positive results already published by the writer (8). Subsequent experiments have confirmed the conclusion then reached that Swollen-shoot is caused by a virus.

To exclude the action of other factors, three plants were budded which had been enclosed in insect-proof cages for a year. The first definite symptoms appeared three months later on all plants; controls still remain healthy. Ten healthy uncaged plants in an uninfected plot were also budded; all developed Swollen-shoot, but all untreated plants remain healthy. At Aburi, ten miles from the nearest known case of the disease, 90 plants were budded with Swollen-shoot. All developed the chlorosis now regarded as an early symptom of the disease, and when 18 had developed typical swellings, all were destroyed to avoid infecting native farms in the district.

(*c*) Seed.

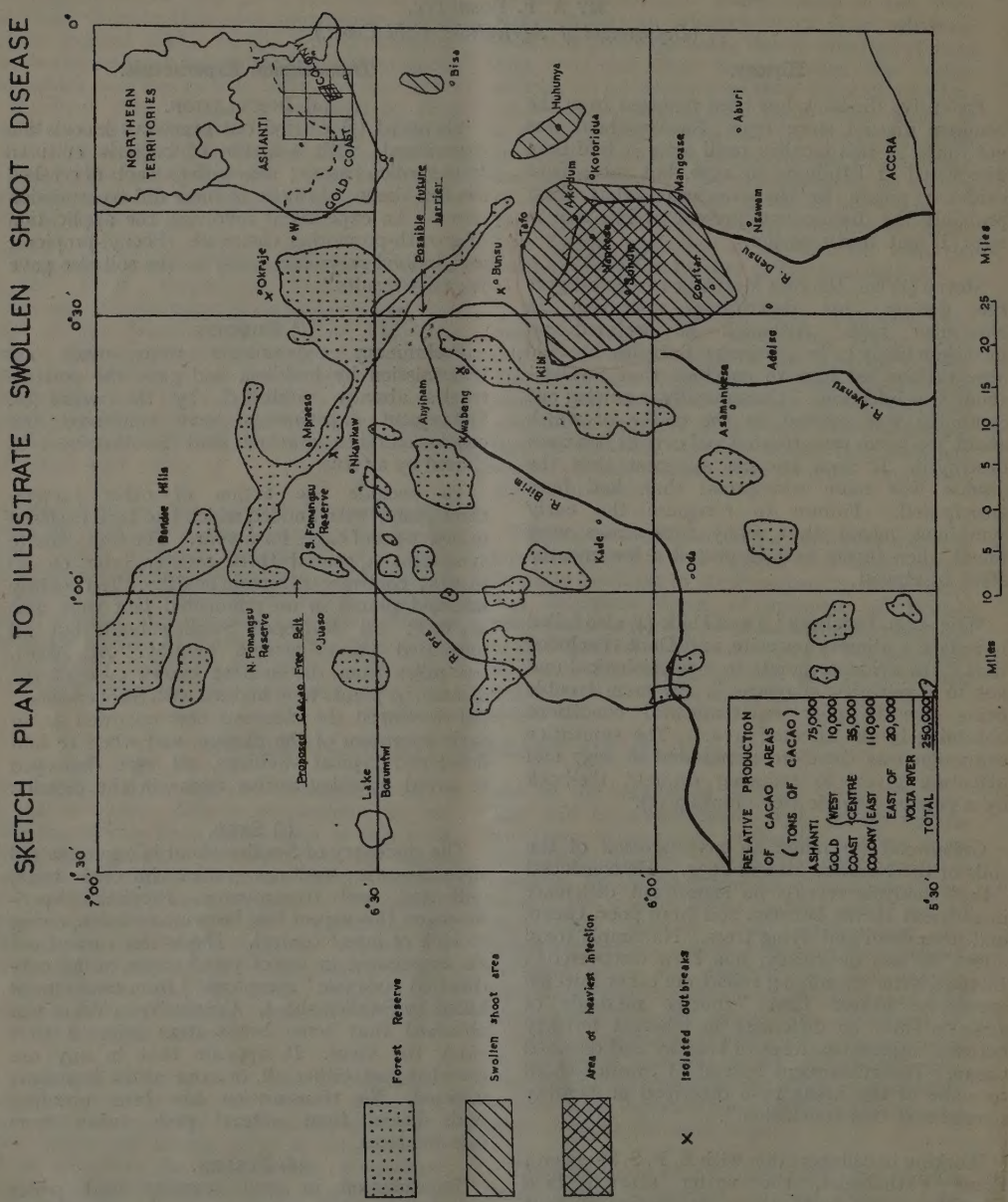
The discovery of Swollen-shoot in 2-months old squirrel-sown seedlings under infected trees, indicated seed transmission. Previous experiments on this aspect had been inconclusive, owing to lack of insect control. The writer carried out an experiment in insect proof cages, using only dwarfed pods (*see* "symptons") from trees almost killed by Swollen-shoot. Conclusive evidence was obtained that some beans from infected trees carry the virus. It appears that in any one dwarfed pod, either all, or none of the beans are infected. No transmission has been obtained with beans from normal pods taken from infected trees.

(*d*) Pollen.

Transmission in seed suggests that pollen transference of the virus cannot be disregarded. Experiments are in progress to test this possibility.

(*e*) Insect.

In the search for the vector, all available cacao-sucking Hemiptera were collected, fed on infected plants, and then caged on healthy seedlings. To


SKETCH PLAN TO ILLUSTRATE SWOLLEN SHOOT DISEASE
NORTHERN TERRITORIES
ASHANTI
GOLD COAST
Bandae Hills
N. Fomangsu Reserve
S. Fomangsu Reserve
Proposed Cacao Free Belt
Lake Bosumtwi
Possible future barrier
R. Birim
R. Pra
R. Ayensu
R. Densu
Mpraeso
Nkawkaw
Juaso
Okraje
Bisa
Bunsu
Tafo
Huhunya
Koforidua
Akropum
Nankese
Kyebi
Kibi
Kwabeng
Anyinam
Kade
Oda
Asamankese
Mangoase
Cantor
Adeiso
Aburi
Nsawam
ACCRA
RELATIVE PRODUCTION OF CACAO AREAS (TONS OF CACAO)
ASHANTI 75,000
GOLD COAST COLONY (WEST 10,000
CENTRE 35,000
EAST 110,000
EAST OF VOLTA RIVER 20,000
TOTAL 250,000
Forest Reserve
Swollen shoot area
Area of heaviest infection
Isolated outbreaks
Miles 10 5 0 5 10 15 20 25 Miles
7°00'
6°30'
1°00'
0°30'
0°
6°00'
5°30'

agree with field observations on the spread of Swollen-shoot, the vector should attack plants of all ages, attack shaded cacao trees less readily than unshaded, be sufficiently common to explain radial spread from the original infected tree, and small enough to be wind-borne for considerable distances. On these grounds, the Cacao Psyllid (*Mesohomotoma tessmanii*), the Aphis (*Toxoptera aurantii*) and the Thrips (*Heliothrips rubrocinctus*) might be responsible for spreading the disease. To date *M. tessmanii* (9) is the only species to give positive results, but a definite statement can be made only after large-scale experiments are concluded. Other species tested belong to the following families :—

Capsidae.	Fulgoridae.
Coreidae.	Dictyophoridae.
Membracidae.	Ricaniidae.
Cercopidae.	

Symptoms.

Generalisation is difficult because of considerable variation in the degree to which the various symptoms develop. All the symptoms to be described may appear together or separately, conspicuously or to a slight degree.

The first recognisable symptom is usually a chlorosis of the young leaves, which, on close inspection, are seen to be mottled with a fine mosaic. This mosaic may develop later into a general chlorosis, or rarely, it may be masked by further development of chlorophyll.

Some degree of leaf shedding may precede, but usually follows, this chlorosis. Subsequent leaf-flushes are much reduced, and infected plants are unable to recover from damage by Capsid bugs (*Sahlbergella* spp.). The period between the first appearance of leaf mosaic and complete defoliation (in the absence of Capsids) varies with locality; on observation plots near Tafo, it is as short as four months; 9 to 12 months is probably more usual. Die-back follows rapidly after defoliation, though the main trunk may not die down to ground level for a year or more. Any recovery is merely transitory.

The swellings which have given the name to the disease appear to depend for their development on a vigorous flush of growth. They are always more pronounced on chupons than on fans, and sometimes appear on a basal chupon before leaf mosaic has developed. If defoliation and dieback occur rapidly, typical swellings may not develop.

In many cases, swellings are only found on the thin leafless shoots (with shortened internodes) which develop from axillary buds, usually after the apical bud has been checked. Abnormal stimulation is indicated, however, as these twigs are sometimes so developed that they produce a resemblance to Witches' Broom.

Trees in the early stages of infection often bear a heavy crop, but after defoliation starts few pods are formed, and these are dwarfed and rounded although previous to infection the trees were bearing normal Amelonado pods. (It should be remembered that at least 90 per cent. of Gold Coast cacao is uniform *T. leiocarpa*, or Amelonado. Trees of the Calabacillo type are very rarely found and then always in association with other Trinitario types.)

Although gradations occur, two distinct extremes of Swollen-shoot are recognised by some workers. The commonest form is characterised by marked chlorosis and rapid dieback, with few swellings, seldom exaggerated. The other type, known as the "mild" or "Bisa" strain, is accompanied by very little chlorosis, slow deterioration of the trees, and many very pronounced swellings. Budding with each type has reproduced in the stocks similar symptoms to those shown by the plant from which the scion was taken.

Control.

General observations by the Agricultural Officers engaged on shade-tree planting in the affected area, and detailed observations at Tafo Research Station, all point to the conclusion that Swollen-shoot is spreading rapidly, so rapidly that other forms of die-back (other than Capsid damage) in the Eastern Province, are almost completely masked by this disease. Infection with Swollen-shoot almost invariably precedes dieback—there has been no evidence of physiological dieback or Sahlbergella damage predisposing the tree to Swollen-shoot. As soon as conclusive evidence of transmissibility was obtained, a policy of cutting out all infected trees, and those suspected of infection, was put into operation on the Tafo plots. The spread of the disease at Tafo has been independent of shade—in some plots the first tree to be infected stood directly under a shade tree. In other areas, shade appears to delay infection. The disease spreads rapidly from tree to tree, so that there is often a clear-cut line between dying trees and trees in excellent health. There have been no cases of drought or exposure dieback at Tafo.

It is evident that the control measures devised to cure drought dieback by improving the environment for cacao, are of little or no value as preventatives, or cures for Swollen-shoot disease. The area for some 250 square miles around Akwadum is regarded as too heavily infected to justify control measures. All that can be done is to restore forest conditions suitable for the re-establishment of cacao in the future. Shade-tree planting must play a less important part in reafforestation than was thought at first. Grassland, to which, Dade (*loc. cit.*) states, abandoned cacao farms were reverting, is merely a transition phase, usually following food crop cultivation after the cacao has died. On the Accra

plains, Irvine* has shown (at Achimota) that grass is maintained only by repeated burning and cultivation which prevents the normal re-establishment of secondary forest. After repeated clearing under cacao for many years, a lag would be expected before forest species develop. In less than ten years, many abandoned cacao farms in the Nankese area are now in dense bush, most of the secondary forest tree species are well represented as saplings six to ten feet high with which planted shade-tree (*Saman samanea*) cannot compete successfully.

Acknowledgments.

I take pleasure in acknowledging the helpful criticism given with the preparation of this paper by Messrs. G. S. Cotterell, H. Nicholas, M. Greenwood and F. L. Squibbs.

* F. R. Irvine: private communication.

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COMPOSITION OF CHLOROPHYLL AS INDEX OF SUGAR-CANE GROWTH.

THE trend of present day thought is in the direction of using the plant itself as indicator of fertilizer requirements. The difficulty lies in the determination of the particular tissues of the plant which will provide the best indication, for the elements constituting plant food are not uniformly distributed throughout the plant tissues. The example there given concerned nitrogen and the content of that element in certain specific areas of certain leaves. A recent paper by C. E. Beauchamp and F. Lazo (1) bears on the same problem. Here, however, the comparison is drawn between growth and the crude alcoholic extract.

Previous work, which has been described in a number of earlier publications, had shown that a marked correlation existed between growth (average stalk length and stalks per stool) and the factor $K_2O/N+P_2O_5$ calculated from the mineral content of the crude chlorophyll, the latter being determined from the sixth leaf counting from the base at 3.5 months after planting, growth measurements being taken at harvest, 23 months after planting. The soil in the present case was Matanzas Red Clay.

The main conclusions drawn are that increments of potash increased the amount of that element in the crude chlorophyll and of growth however measured including per cent. available sugar; phosphorus showed no corresponding increments and the same may be said of nitrogen which, however, reduced the sugar content of the juice.

A number of inter-correlations are disclosed. Thus increments of potash led to increases of both phosphorus and calcium in the crude chlorophyll while increments of phosphorus and nitrogen raised the content of potash when the fertilizer content of this latter was low. Such correlations extend to other elements, increments of potash raise the calcium, but diminish the magnesium content but increments of phosphorus have the reverse effect in both cases. These, and other facts given, seem to indicate that, for the optimum development of the crop, there is an optimum balance between the plant food elements which is reflected in the ratio between those elements as they exist in the crude chlorophyll. Such inter-correlations naturally affect and complicate the problem of finding any simple factor which will be a reliable measure of growth; for the present, the most indicative factor found is that given above, namely $K_2O/N+P_2O_5$. The correlations discussed are illustrated by graphs and the corresponding coefficients are not worked out.—(*Inter. Sugar Jr.*, 42, p. 9.)

(1) *Proc. XII Ann. Conf. Assoc. Tech. Azuc. de Cuba*, 1938, p. 34.

OBITUARY.

DR. J. R. DICKSON, O.B.E., M.B., B.SC., D.P.H.

It is with deep regret that we have to announce the death of Dr. J. R. Dickson which took place suddenly in Port-of-Spain on the afternoon of the 9th April while he was attending a meeting of the Central Board of Health.

Dr. Dickson joined the staff of the College in October 1931 as Medical and Health Officer, resigning from this post in December 1939. He will be remembered by the staff and many old students as a man of very gentle and kindly disposition who rendered loyal service to the College during his period of office. His career in the medical service of the Colony of Trinidad which he joined in 1891 was one of distinction. He served in every branch of his profession, retiring as Deputy Surgeon and Medical Inspector of Health. After his retirement he continued to take an active part in matters connected with the health of the Colony and was untiring in his efforts for the advancement of child welfare and education.

BANANA LEAF SPOT MYCOSPHAERELLA MUSICOLA, THE PERFECT STAGE OF CERCOSPORA MUSAE ZIMM.

By R. Leach, B.A., A.I.C.T.A.

(*Plant Pathologist, Banana Leaf Spot Control Division, Department of Science and Agriculture, Jamaica.*)

Introduction.

Cercospora musae Zimm. was first described by Zimmerman (9) in 1902, when this fungus was recorded as the cause of leaf spot of bananas in Java. Leaf spot ('sigatoka') has been reported as being the cause of serious losses to bananas in many countries since that date and the history of the disease has been well reviewed by Popenoe (5). No perfect stage of the fungus has been recorded although Simmonds (6) thought that the irregular rounded bodies of varying size formed in cultures of *C. musae* might represent immature perithecial structures. Parham (4) suggested that a *Mycosphaerella* might be the perfect stage of *C. musae* but was unable to establish it.

Recent work by the writer has demonstrated the presence of an ascigerous stage of *C. musae* in Jamaica. A description of this ascomycete was submitted to the Director of the Imperial Mycological Institute, Kew, England, for advice regarding nomenclature and it has been decided to name the fungus *Mycosphaerella musicola*.

This paper describes this perfect stage of *C. musae*, mentioning the way in which it was found and discussing the possible importance of ascospore infection in the etiology of leaf spot disease of the Gros Michel banana in Jamaica.

Technique.

(*a*) *Study of natural infection.*—The following method was employed to study the natural infection of banana leaves.

Lactophenol is heated in a specimen tube to 100°C in a water bath and leaf specimens, cut to the size of a long cover slip, are then immersed in it. The leaf curls up at first but soon uncurls and becomes transparent—the surface of the leaf can be examined at this stage by staining with cotton blue in lactophenol after cooling has disposed of the internal air bubbles. If specimens are required for examination later, they are best decolorized by immersion in 95 per cent. alcohol after which they are preserved in a fresh solution of alcohol. The specimens are transferred to water prior to examining the surfaces by staining with cotton blue or methylene blue and neutral red [Kuribayashi (1)]. The germinating spores of *C. musae* can be seen forming typical appressoria (Pl. 1, Fig. 1) over the stomata through which infection occurs in the manner described by Stahel (7). Intensity of infection is estimated by observing the number of infections on an area of leaf measured with the aid of a calibrated mechanical stage.

(*b*) *Ascospore discharge.*—The ascospores of *Mycosphaerella musicola* were found by suspending specimens of spotted banana leaves horizontally above sterilized slides covered with plain agar in an atmosphere sufficiently humid for ascospore discharge but not for the production of the *Cercospora* conidia. Spores of various other ascomycetes are discharged on to the agar among which the spores of *M. musicola* are often inconspicuous. Fortunately, however, the latter germinate quickly and their mode of growth is so characteristic that they can then be clearly distinguished. Spore discharge is therefore arranged over a period of 18 to 24 hours, after which the germinated ascospores (Pl. 1, Fig. 2) are most conveniently observed by flooding the surface of the agar with a weak solution of cotton blue in lactophenol. When it is necessary to examine a large number of slides, the rapid growth of the various extraneous fungi over the surface of the agar makes it advisable to prevent all further growth after 24 hours by flooding the slides with lactophenol or a ten per cent. solution of copper sulphate before putting them into a moist chamber to prevent the agar from drying.

Observations and Experiments.

During an examination of some banana leaf specimens upon which a quantitative estimation of natural conidial infection was being made, a number of two-celled spores were seen which had developed germ-tubes with appressoria over the stomata (Pl. 1, Fig. 3) similar to those formed by the germ tubes of *C. musae* (Pl. 1, Fig. 1). At first it was thought that these spores might merely be two-celled conidia but the number seen and the uniformity of their shape indicated that they might be ascospores of the perfect stage of *C. musae*.

Among the various spores, such as those of *Leptosphaeria* spp. and *Mycosphaerella minima*, described by Stahel (7), obtained by suspending portions of spotted leaves over agar slides, two-celled spores, often in groups of eight, were found which looked like those seen germinating and forming appressoria on the leaf. Perithecia giving rise to these spores were found without much difficulty.

Single spore isolations of these two-celled ascospores gave rise to cultures on banana leaf-extract agar exactly like cultures of *C. musae* and from these ascospore cultures conidia of *C. musae* were obtained in a manner somewhat similar to that described by Meredith and Butler (3). Inoculations on heart leaves of Gros Michel banana plants with suspensions of these

conidia obtained from single-ascospore cultures have repeatedly given rise to typical leaf spot lesions on which typical conidia of *C. musae* have been freely produced.

In this way definite proof has been obtained that the ascomycete, now named *Mycosphaerella musicola*, is the perfect stage of the fungus *C. musae*. Although these investigations are primarily concerned with the etiology of leaf spot in relation to the Gros Michel banana, it may be noted here that similar single ascospore isolations have been obtained from perithecia on diseased leaves of the Cavendish banana. There is little delay in the maturation of perithecia in leaf spots because ascospore discharge has been obtained from all spotted leaves except the fourth (the first leaf to show spots). The formation of perithecia and the duration of spore output have not been studied in detail.

Description of Mycosphaerella musicola.

Perithecia—Diameter 46.8μ—72.0μ, mean 61.8μ; dark brown or black, amphigenous, scattered on mature leaf spots, erumpent, short protruding ostiole, dark wall well defined (Pl. 1, Fig. 4).

Asci—Length 28.8μ to 36.0μ, breadth 8.0μ to 10.8μ; oblong clavate.

Ascospores—Length 14.4μ to 18.0μ, mean 16.7μ; breadth 3μ to 4μ; one-septate, hyaline, obtuse-ellipsoid, upper cell slightly broader, constriction at septum not marked (except when dead and shrivelled), oil globules irregular and often inconspicuous (Pl. 1, Fig. 5).

Paraphyses—None.

This species of *Mycosphaerella* is intermediate in its measurements between *M. minima* described by Stahel (7) and *M. musae* (Speg.) Syd. mentioned by Wardlaw (8). The spores of *M. minima* have been frequently noted alongside those of *M. musicola* during these investigations; the former, however, are readily distinguished by their consistently larger size, a marked constriction at the septum and conspicuous oil globules, while on agar the type of growth differs from *M. musicola* in being more rapid (as stated by Stahel) and having a finer germ tube.

Ascospore Germination.

Germination tests have so far been carried out only at laboratory temperatures, namely 70° to 84°F, when the quickest germination occurred in 2½ hours on plain agar. The germ tubes grow out almost invariably from both ends of the spore although not simultaneously, but never from the sides. The robust hyphae, 2.0μ wide, grow out in line with the long axis of the spore, side branching being absent during the first 24 hours in which the rate of growth does not exceed 5μ per hour; the germinated spore thus assumes the characteristic form shown in Pl. 1, Fig. 2.

Often associated with the ascospore of *M. musicola* are other two-celled spores of approximately the same dimensions which germinate in a somewhat similar manner in the first 24 hours. The germinated ascospore of *M. musicola* is recognisable by the following characters—(1) no marked constriction at the septum, (2) an unusually robust, slightly wavy, germ tube making only a small constriction at the ends of the spore, (3) a growth rate not exceeding 5μ per hour on plain agar.

After 24 hours the germinating ascospore is even more readily recognized because one or both cells of the spore start to become dumb-bell shaped and later the older cells of the germ tube also do likewise (Pl. 2, Fig. 6), at the same time side branching increases in extent. The dumb-bell shaped cells are similar to those usually formed during germination of the conidia of *C. musae* on agar cultures. They indicate that germination on agar is unnatural because dumb-bell shaped cells are not formed during natural germination on the banana leaf when incidentally there is frequently only one germ tube. The writer, therefore, considers that no germination tests with ascospores of *M. musicola* or conidia of *C. musae* are valid unless the natural form of germination is known to occur in the manner shown clearly in Pl. 1, Fig. 3 and Pl. 1, Fig. 1. For this reason all critical tests of germination need to be carried out on the banana leaf and investigations along these lines are now in progress.

Experimental Ascospore Infection.

Although ascospores of *M. musicola* have not been produced in culture, infection by them was readily demonstrated in the following experiment.

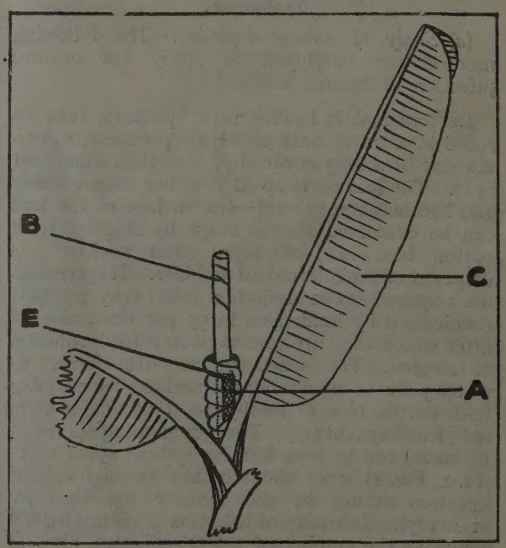

Diagram 1.

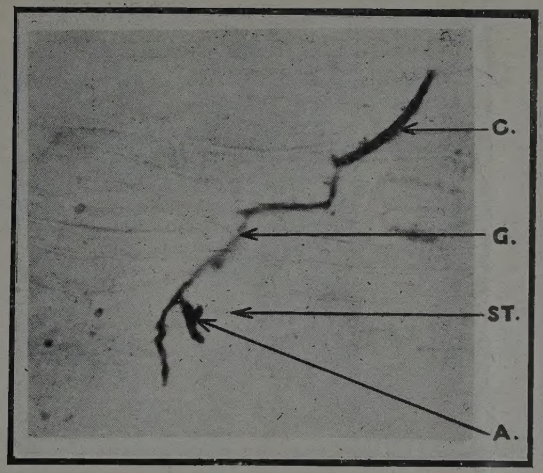

FIG. 1.

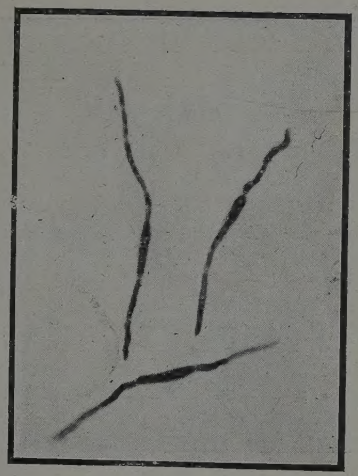

FIG. 2.

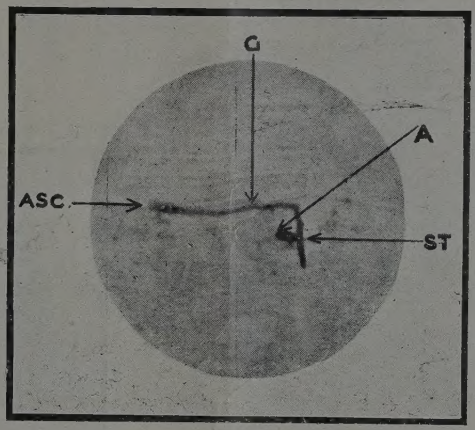

FIG. 3.

FIG. 4.

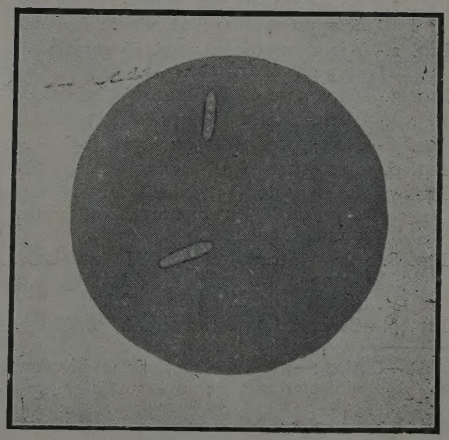

FIG. 5.

For explanation of figures *see* Plate II.

PLATE II.

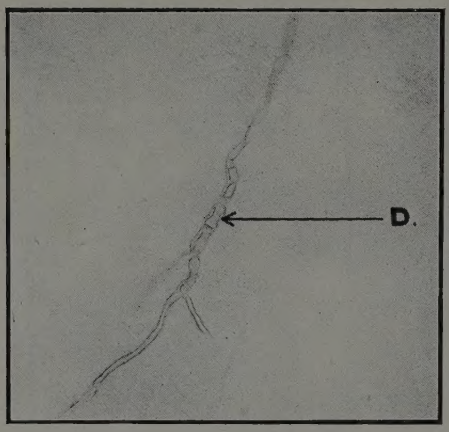

FIG. 6.

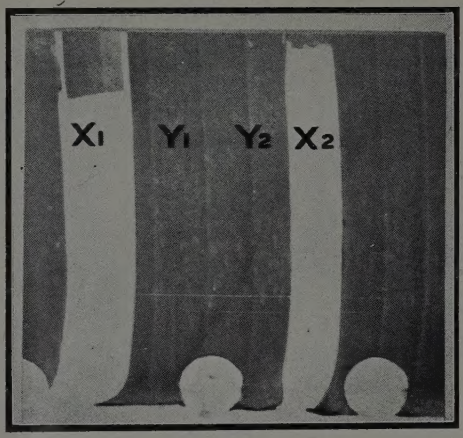

FIG. 7.

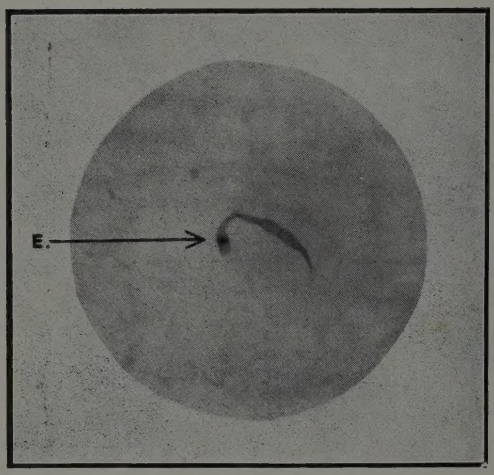

FIG. 8.

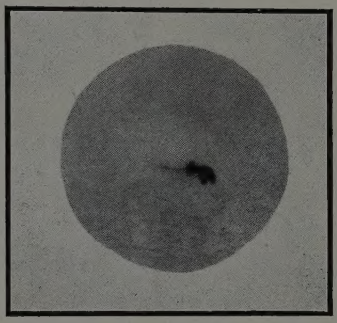

FIG. 9.

(All Microphotographs × 370.)

FIG. 1.—Conidium of *C. musae* infecting stoma of banana leaf. c, conidium; g, germ tube; a, appressorium; st, stoma (mb/nr).

FIG. 2.—Ascospore of *M. musicola* germinating, 12 hours after being discharged from perithecia on to plain agar. (cb).

FIG. 3.—Ascospore of *M. musicola* infecting stoma. asc, ascospore. (mb/nr).

FIG. 4.—Perithecia of *M. musicola*. (sgo).

FIG. 5.—Ascospores of *M. musicola*. (u).

FIG. 6.—Ascospore of *M. musicola* after 48 hours' germination on plain agar. d, dumb-bell cells. (u).

FIG. 7.—Leaf spots ('streaks') formed by experimental infection with ascospores of *M. musicola*; X_1 and X_2 cut out for estimation of spore intensity; Y_1 and Y_2 left for estimation of streak intensity.

FIG. 8.—Dead ascospore of *M. musicola* after infecting a stoma on the lower surface of a banana leaf causing the formation of a 'streak'. e, hypha (Black spot) entering leaf between guard cells of stoma. (mb/nr).

FIG. 9.—Stomatal pore in a streak, filled by hyphae of a stomatopodium. (mb/nr).

N.B.—Stains :—mb/nr = methylene blue/neutral red; cb = cotton blue; sgo = safranin/gentian violet/orange g; u = unstained.

A portion of heavily spotted banana leaf, in which perithecia of *M. musicola* were known to be functional, was held between two pieces of wire gauze (A; Diag. 1) bent in such a way that it could fit closely round the base of a cylindrical banana heart leaf (B; Diag. 1) supported by the petiole of the subtending leaf (C; Diag. 1), without impeding the growth of the heart leaf.

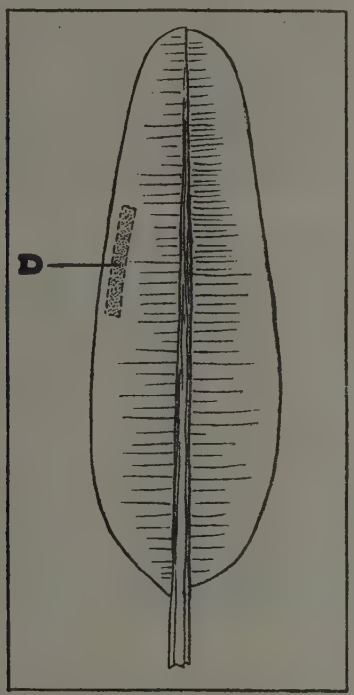

Diagram 2.

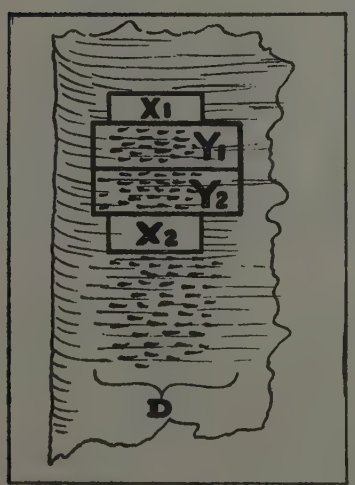

Diagram 3.

The spotted leaf was kept in a humid atmosphere by folding a damp cloth (E; Diag. 1) round the wire gauze so that conditions were sufficiently humid for ascospore discharge but not for inducing the formation of surface moisture required for the production of conidia of *C. musae*.

The gauze was left on for two nights (from 8th November to 10th November) and when the heart leaf finally expanded three days later the infected area (D; Diag. 2) was defined by slight markings made by the edge of the wire gauze in contact with the elongating heart leaf.

Two strips (X_1 and X_2; Diag. 3) were cut out of the 'inoculated' area of the leaf on 18th November in order to estimate the number of spores which had germinated and formed appressoria (infected) over stomata. The result of this examination is given in Table 1A which shows clearly that many ascospores were seen but no conidia. The number of 'streaks' (earliest visible evidence of infection) (Pl. 2, Fig. 7) which developed by 20th December in the intermediate areas Y_1 and Y_2, are shown in the Table 1B. (N.B.—Streak development was not abnormally slow for the time of year and neighbourhood in which the experiment was carried out).

Table 1a.—Intensity of Spore Infection (18th Nov.)

Leaf Specimen.	Length (in.)	Area (sq. in.)	Spore.	Total No. of Spores.	No. Germinating.	No. infecting (appressoria)	No. of spores infecting per sq. in. (Calculated)
X_1	1.02	0.34	Ascospores	196	194	132	388
			Conidia	0	0	0	0
X_2	0.91	0.25	Ascospores	340	336	236	944
			Conidia	0	0	0	0

Table 1b.—Number of Spots ('streaks') (20th Dec.)

Leaf Specimen.	Length (inch.)	Area (sq. inch.)	No. of streaks per sq. inch.
Y_1	1.69	0.93	79
Y_2	1.69	0.93	83

The portions, X_1 and X_2, examined in the laboratory, proved to have been shorter in length than Y_1 and Y_2 and, also, to have been taken from an area where the concentration of streaks was greatest. The figures for spore intensity appear therefore to be unduly high in relation to the number of streaks formed. Two factors, however,

may explain this, namely, (1) the difficulty in estimating the number of streaks when many minute ones join on to each other to form what is probably judged to be one streak and (2) the ascospores, discharged from perithecia close to a leaf in a still atmosphere, were frequently observed in groups (for instance 15 ascospores, of which nine were infecting stomata, were seen in an area of 1.5 sq. mm.).

From the above Tables most, if not all, of the many streaks which developed could be attributed to infection by the same type of spore as those seen causing stomatal infection in X_1 and X_2, *i.e.* by the ascospores of *M. musicola*.

Further evidence of ascospore infection was obtained in a preliminary experiment run on somewhat similar lines to that just described. Both surfaces of streaks were examined under the microscope to see whether the spores which actually caused the infection could be found, because previous observations had often demonstrated the presence of a germinated conidium which had infected a stoma near the centre of similar streaks. Out of 20 minute well isolated streaks formed in this experiment one empty, shrivelled ascospore was seen on the under surface of the leaf near the centre of 15 of the streaks where it had germinated, formed an appressorium and infected a stoma. No spore was detected on five of the streaks while no conidia of *C. musae* were seen associated with any of the streaks and no ascospores or conidia were seen on the upper surface of the leaf. Infecting ascospores can be clearly seen in such cases when stained with methylene blue and neutral red because the originally infected stoma has only one small dot visible at the point of entry between the guard cells under the appressorium (Pl. 2, Fig. 8) while the other stomata of a streak occupied by stomatopodia, as described by Stahel (7), are seen blocked by whole row of hyphal cells (Pl. 2, Fig. 9).

Intensity of Ascospores Infection.

Table 2 gives an example of the number of conidia and ascospores of *M. musicola* observed on the lower surface of a newly opened banana leaf growing in a plantation heavily infected by leaf spot; it shows that natural infection by ascospores can be as severe as that by conidia.

Table 2.—Natural Infection of Banana Leaf.

Area of Leaf	Spore Type.	Total No. Spores	No. Germinating.		No. Ungerminated.
			Not Infecting	Infecting (Appressoria).	
1.3 sq. in.	Conidia (*C. musae*)	75	25	36	14
	Ascospore (*M. musicola*)	40	4	36	0

Although the output of ascospores per spot is probably far below that of the conidia, ascospore discharge is not dependent upon the presence of surface moisture on the leaf spots. Ascospores can, therefore, be discharged from the lower leaves in a plantation at a time when the shaded position of the leaves prevents the formation of dew, thereby suppressing the production of conidia which require surface moisture for their development. At the same time ascospores are essentially wind borne while the conidia of *C. musae* have been shown to be readily removed from the sporodochia by water but not by wind. Provided, therefore, that there is a large population of heavily spotted leaves in a plantation, it is understandable how ascospores may reach heart leaves in as large numbers as do the conidia.

Discussion.

Recent observations by the writer (2) have shown that a very high proportion of leaf spot infection occurs on the young developing heart leaves of the Gros Michel banana under Jamaican conditions. By the use of various spraying schedules, successful commercial control has been obtained although in practice the fungicidal spray material, *e.g.* Bordeaux mixture, gives little or no protective covering on the surface of the continually unfurling heart leaves. The action of the spray in controlling heavy conidial infections is considered to be largely due (1) to a reduction in spore production on sprayed, spotted leaves and (2) to an inhibiting effect on the germination of any conidia which are removed by dew rendered toxic by contact with the surface of a sprayed banana leaf.

Ascospore discharge from perithecia formed inside a leaf is not affected by spraying in the same way as that of *Cercospora* conidia produced on sporodochia on the surface of a leaf spot. Perithecia of *M. musicola* are amphigenous and therefore eject ascospores from both surfaces of the leaf which in commercial spraying are not often both covered with spray. Since ascospores are essentially wind borne they may reach heart leaves without coming in contact with any spray material. Ascospore infection may therefore be more difficult to control than conidial infection. Preliminary observations indicate that ascospore production and discharge is only seasonal; this may account for some of the variations in the standard of success attained by growers starting to control heavy attacks of leaf spot by spraying.

It would seem essential to pay closer attention to crop hygiene, *i.e.* by disposal of all dead spotted leaves, prior to the season of ascospore discharge. It is probable that the disease was spread comparatively rapidly throughout the Island by ascospore infection since bananas are usually transported to the coast packed with infected trash leaves from which the dissemination of ascospores might be easier than that of conidia.

Acknowledgments.

The writer is indebted to Dr. S. P. Wiltshire, Director of the Imperial Mycological Institute, Kew, England, for his assistance in regard to nomenclature, and to Mr. A. F. Butler, Agronomist in charge of Cedar Grove Experimental Station, Research Department, United Fruit Company, Jamaica, for so kindly taking the micro-photographs published in this paper.

Summary.

1. The way in which the perfect (ascigerous) stage of *Cercospora musae* has been established is described.

2. A description is given of this new ascomycete, *Mycosphaerella musicola*.

3. Experiments relating to ascospore infection are recounted.

4. The intensity of natural ascospore infection can be as heavy as that of conidial infection under certain conditions.

5. Preliminary observations indicate that ascospore discharge is seasonal.

6. The potential importance of ascospore infection is discussed in relation to the etiology of banana leaf spot disease.

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MOVEMENT OF POTASSIUM IN IRRIGATED AND FERTILIZED RED SANDY CLAY.*

The following summary gives the main results of an investigation carried out at the Soil Research Laboratory, Agricultural Research Station of the Jewish Agency, Rechoboth, Palestine, to trace the movement and fate of potassium added to soil as a fertiliser salt.

1. Before application of fertilizer, the potassium content of a red sandy clay was found to be distributed as follows: non-exchangeable and therefore slowly available potassium, 81 to 92 per cent.; soluble and exchangeable potassium, 8 to 19 per cent.
2. When potassium sulphate is applied to this soil in four portions at a rate of 1800 g. per nine sq. m., or when double this rate is used, the largest part of applied fertiliser is retained in the upper soil layer (0-30 cm.).
3. Potassium introduced into the soil by fertilizer treatment was distributed to a depth of 60 cm. in the following proportion: non-exchangeable potassium, 60 to 94 per cent.; soluble and exchangeable potassium, 6 to 40 per cent.
4. There is a direct relationship between the amount of potassium applied and the amount of potassium retained by the soil. When the fertilizer ration applied is doubled, the amount of total, exchangeable, and soluble potassium retained in the upper soil layer (0 to 30 cm.) is somewhat more than double, and also the amount of potassium retained in the second soil layer (30 to 60 cm.) is substantially increased.
5. By irrigating with double instead of normal ration of water, the concentration of total, soluble, and exchangeable potassium in the second soil layer (30 to 60 cm.) is increased.
6. When irrigation is not carried out in summer, soluble potassium ascends from the deeper layers to the upper soil layer (0 to 30 cm.); in winter, an opposite movement occurs, and there is a loss of soluble potassium which decreases with increasing depth.
7. Successive summer irrigations with one or two cu.m. of water per irrigation lead to considerable losses of total, soluble, and exchangeable potassium from the soil by leaching.
8. A direct relationship between the rate of loss of total, exchangeable, and soluble potassium from the soil by leaching and the amount of water applied in irrigation exists only in plots which have received a normal fertilizer ration.

The effect of potassium fertilizer on the soil pH is slight. In the upper layer (0 to 30 cm.), there is after fertilization a slight movement towards increased alkalinity, and in deeper layers a slight movement towards greater acidity. With double the normal ration of fertilizer, the effect on soil pH was more marked. On repeated irrigation, soil pH changes due to fertilizer application are nullified.

* By D. Lachower in the *Journ. Agric. Sci.*, 1940, Vol. XXX, p. 498.

IMMORTELLE DISEASE.

By R. E. D. Baker.
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I. Introduction.

In recent years the two Immortelles, *Erythrina micropteryx* and *E. glauca*, commonly known as the 'Anauca' and 'Bocare' respectively, which are used as shade trees in Trinidad cacao plantations have been severely attacked by a bark disease caused by the Ascomycetous fungus *Calostilbe striispora* (Ell. & Ev.) Seaver. This fungus is known from elsewhere in the Western Tropics having been recorded by Stahel from Surinam (9) on Immortelles and from Costa Rica (10) on cacao. More doubtful records include Nicaragua and St. Lucia. *Sphaerostilbe musarum*, described by Ashby (1) as the cause of Bonnygate disease of bananas in Jamaica, is identical with *Calostilbe striispora* and should be regarded as a synonym of it. It is quite distinct from the *Sphaerostilbe repens* which is associated with root diseases of limes in the West Indies and of rubber in Malaya and Ceylon.

The first Trinidad record was made by Broadway (3) in 1906 from a dying cacao tree in Santa Cruz, and in 1924 Ashby (2) again found it on cacao in the Caura valley. A recent survey made by the Department of Agriculture has shown that it is fairly widespread, but is especially severe in the low-lying Sangre Grande and Manzanilla areas where the soil is heavy and the rainfall high. From 1928 onwards Bocare Immortelles in these areas began to die rapidly and material sent by Stell (11) to the Imperial Mycological Institute was identified as *Calostilbe striispora*. Stell (11) made a preliminary investigation and concluded that *C. striispora* was a weak parasite of little importance except on unhealthy trees suffering from lack of drainage, and that the disease was aggravated by the local practice of piling dead wood and débris around the bases of the trees. Since then the disease has killed many hundreds of Bocare Immortelles and has also attacked the Anauca Immortelle, cacao, and *Hevea* rubber to an appreciable extent. It has also been found once on bois canon (*Cecropia peltata*) and occurs commonly as a saprophyte on cacao husk heaps. The wholesale destruction of the Bocare Immortelle coupled with the discovery of some hundreds of diseased cacao trees and a few diseased rubber trees has caused some concern, especially in the Sangre Grande and Manzanilla areas. In 1939 investigations, the results of which are described here, were undertaken at the request of the Department of Agriculture of Trinidad and Tobago. I am greatly indebted to Mr. E. A. Robinson on whose estate at Sangre Grande the bulk of the work was carried out, and to his manager, Mr. L. A. Ferguson, without whose constant help and co-operation the work would never have been satisfactorily completed. Messrs. C. A. Thorold, Plant Pathologist to the Department of Agriculture, S. H. Crowdy and R. K. McKee of the Imperial College have all rendered valuable assistance with the experimental work.

II. Symptoms.

Differences in host plant have little effect on the disease, its appearance being essentially similar on the two species of Immortelle, cacao and rubber. The following description therefore applies actually to the disease as it appears on the Bocare Immortelle, on which it is most commonly found.

It is a disease of the bark,* not of the roots as was at first thought, and its lesions may be found anywhere on the trunk of the tree, on the main branches, on the buttress roots and on the main roots. It has been found on branches as high as 45 feet above the ground and also on the trunk and main roots below ground level. Attacks are most abundant on the buttress roots at or near ground level. The rhizomorphs of the fungus are found in the bark and secondary phloem, and sometimes in the wood, and there is usually an especially thick mat of them in the cambial region. They are somewhat flattened and white at first but gradually turn from white through mauve to purple, and finally to blackish purple. Their internal tissues remain white. The mat of rhizomorphs in the cambium is obvious to anyone familiar with the disease and renders its field diagnosis, by stripping off the bark from a suspected lesion, a relatively simple matter. The bark of Bocare Immortelles is soft and spongy and appears to provide an ideal medium for the fungus; that of Anauca Immortelles, cacao and rubber is harder and thinner and the spread of the disease is slower.

The spores of the fungus, which are of two kinds, are formed abundantly in coremia and perithecia on the surface of diseased lesions. The coremia are very large, being 3–10 mm. high, with dark red heads up to 3 mm. in diameter and white stalks. The four-celled conidia are also very large, measuring roughly 50 × 14μ (Table I). They are a dark red colour in the mass and are often immersed in a drop of fluid. The conidiophores have a swelling just below each conidium and are interspersed with long septate paraphyses (Fig. 1).

The perithecia are superficial, pale greenish yellow in colour, and densely caespitose. The ascospores are again very large (Table I), being similar in size to the conidia, but they are two-celled and markedly striate (Fig. 2).

* The term 'bark' used in this article includes all the tissues outside the cambium.

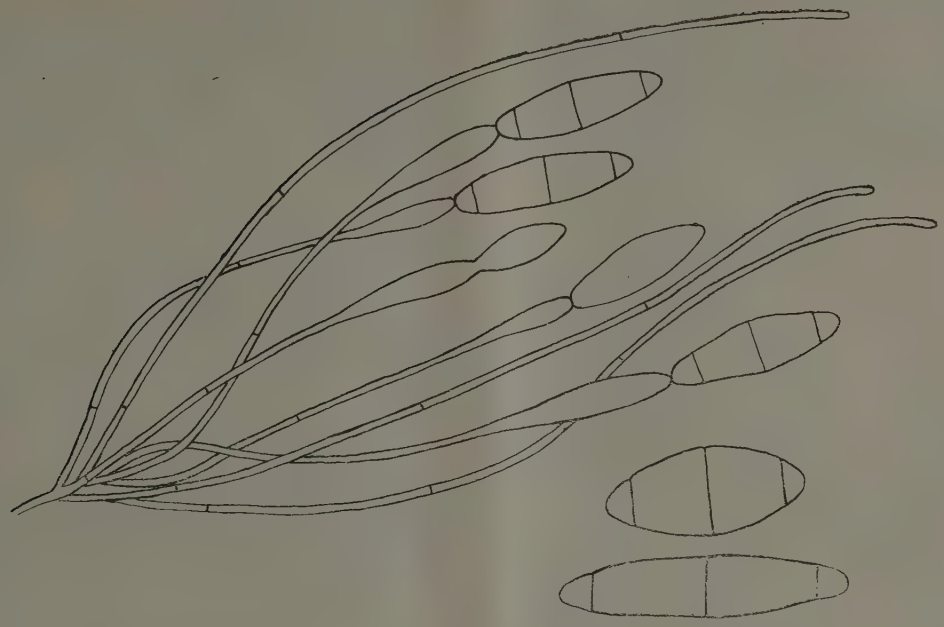

FIG. 1.

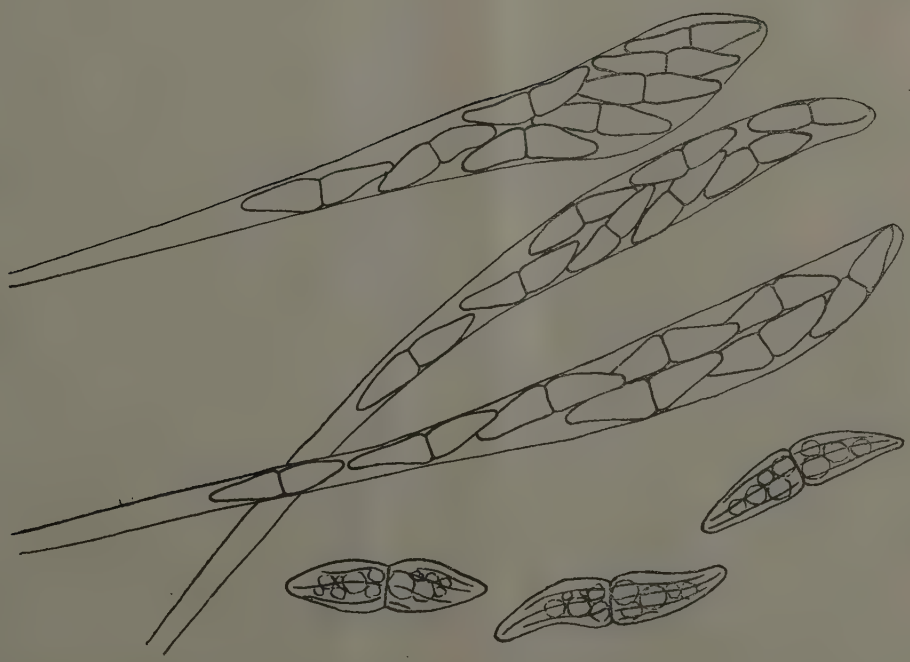

FIG. 2.

The conidial fructifications or coremia are produced first and are especially abundant in wet weather. They are soon followed by the perithecia. Both are readily visible to the naked eye but are not as valuable for field diagnosis as the rhizomorphs, as during dry weather spore formation may be largely suppressed, whereas an examination of the cambium will always demonstrate the presence of rhizomorphs.

Table I.

SPORE MEASUREMENTS.

Source of Spores.	Ascospores		Conidia	
	length	breadth	length	breadth
Immortelle ...	53.1	12.1	51.5	13.5
do. ...	—	—	47.0	13.7
Potato block culture of Immortelle material	—	—	49.5	13.3
do. do. ...	—	—	48.3	13.5
Immortelle bark block culture of Immortelle material	—	—	47.4	13.3
Cacao ...	45.1	12.6	47.3	15.5
Rubber ...	49.3	12.6	44.7	15.5
Banana (Jamaica)	43.8	10.7	—	—
Potato block culture of banana material	—	—	47.8	14.4

III. Mycological Notes.

Calostilbe striispora was first described as *Nectria striispora* Ell. & Ev. on bark and rotten wood from Central America (4). In 1910 Seaver (6) described it in the 'North American Flora' as *Macbridella striispora* (Ell. & Ev.) Seaver, and later Seaver (7) transferred it to the genus *Calostilbe*. The synonymy of this fungus is further discussed by Mason (5).

Calostilbe striispora has several features of interest. The large size of its spores (Table I) would appear practically to preclude distribution through the air, particularly since the heads of the coremia are often immersed in a drop of liquid. It is therefore probable that the disease is most commonly spread by water and by the movement of débris containing the spores or mycelium of the fungus. This is borne out by the observation that the disease occurred first on alluvial flats and along the banks of rivers subject to flooding. As noted by Stell (11) the custom of piling dead wood and other débris round the trees probably hastens the spread of the disease.

It seems most probable that infection occurs through wounds in the bark of the trunk and main roots—young natural infections apparently spreading from wounds have been observed and inoculations without wounding have proved unsuccessful. It is however immaterial for practical purposes whether the fungus can gain entry through natural orifices such as lenticels or through minute wounds made by insects, as all Immortelles, cacao and rubber trees are repeatedly damaged by the implements of the labourers, and large open wounds suitable for infection are regularly available. In the inoculations, infections were only successful through deep wounds; shallow wounds which just penetrated the bark were never infected.

Both ascospores and conidia germinate readily in water or moist air, but the ascospores show a longer initial lag than the conidia. Germination of conidia was over 90 per cent. after six hours at a tropical temperature while under similar conditions, ascospores required twenty-four hours to reach 50 per cent. The colonies develop slowly on both natural and artificial media and form conidia readily on materials rich in carbohydrate such as potato blocks. Ascospores have never been produced in culture.

Successful inoculations with mycelium from cultures, mycelium in living bark, and conidia were made in Bocare and Anauca Immortelles and the fungus was readily re-isolated from the inoculations.

IV. Field Observations.

Immortelle disease is very common and is doing great damage in certain areas of Trinidad. It also occurs more rarely throughout a wide area. It is most abundant where cacao is grown under the shade of Bocare Immortelles on a heavy soil under a heavy rainfall. In such areas it has been epidemic on Immortelles and has also attacked old or unhealthy cacao trees, and occasionally unhealthy rubber trees.

Observations made in these areas show that it is a disease which thrives under moist conditions, being especially common along the banks of rivers which are liable to flooding. In the dry season there is a marked falling off in natural infection and some trees exhibit a considerable degree of recovery. Inoculation is also very much more difficult in dry weather. This dry season recovery is interesting as it suggests that there is an improvement in the physiological condition of the trees in dry weather, and that for several months of the year parts of Trinidad are really too wet for the Bocare Immortelle.

Attacks occur on the trunk, buttress roots, and main roots especially near ground level. On several occasions searches were made for young lesions and an examination of these suggested that they had spread from wounds. One instance of spread by direct contact between Immortelle and cacao roots was found. It is not obvious how attacks which occur high up the trunk are initiated.

Bocare Immortelles succumb to the disease quickly, Anaucas apparently much more slowly. As soon as the bark dies and falls away the sap

and heart wood are attacked by *Fomes Auberianus* which swiftly destroys them, causing the trees to crash with severe damage to the surrounding cacao. *Fomes Auberianus* is closely allied to the *F. lignosus* which causes serious root diseases of rubber and other trees elsewhere. *F. lignosus* is unknown in Trinidad and *F. Auberianus* does not behave in this way, although it is very common on fallen trees in plantations and in natural forest.

C. striispora is able to exist as a saprophyte as well as parasitically. It is still active on fallen Immortelle trees until these have reached an advanced state of decomposition and is commonly found on cacao husk heaps and on heaps of diseased pods which have been collected and left unburied in wet weather.

V. Inoculations.

In the course of the investigations over a thousand inoculations were made on Bocare and Anauca Immortelles and on cacao trees, of which about 25 per cent. were successful. This low percentage success suggests that environmental conditions are of considerable importance and that in certain circumstances the physiological condition of the trees is such that they are immune or highly resistant to the disease.

Once the parasitism of the fungus had been demonstrated by means of pure culture and spore inoculations a rapid method of inoculation for work on environmental conditions, varietal susceptibility, etc., was required. The following technique was employed. Cylinders of healthy bark about half an inch in diameter and in depth reaching just to the cambium were removed with a hollow punch and replaced by a similar cylinder of diseased bark. This was gently hammered into position, labelled with a metal tag tacked into the tree and left for one, two or three months. After the requisite interval the bark was cut out and the area to which the disease had spread was measured. The disease usually spread more rapidly up and down the tree than it did sideways, and for purposes of calculating their area, diseased lesions were treated as ovals. This simple technique gave satisfactory results in most cases. Sealing the wound with a mixture of vaseline and paraffin wax appeared to retard the development of the fungus, and covering the wounds with watch-glasses or irrigating them with a wick leading from a tin of water nailed to the tree gave a slightly higher percentage success. Inoculations made in shallow wounds, open wounds or open cuts were usually unsuccessful. Controls were made by removing a cylinder of bark and immediately replacing it. No controls were attacked. In a successful inoculation rhizomorphs could be seen in the cambium after one month, and after two or three months these had spread over a considerable area and conidia and perithecia appeared on the surface.

Series of inoculations, each replicated at least ten times and repeated at two or three different seasons were designed to throw light on the following questions:

1. Is the fungus a true parasite or merely an early saprophyte which attacks trees about to die for other reasons?
2. Does vigour confer any resistance on a tree, either Immortelle or cacao?
3. Does the age of a tree have any effect on its susceptibility?
4. Is the Anauca more resistant than the Bocare Immortelle?
5. What is the effect of climate or season on the disease?
6. Can any light be thrown on the method of penetration of the fungus under natural conditions by means of inoculations?

The parasitism of the fungus was amply demonstrated both on healthy Bocare and Anauca Immortelles. All inoculations on healthy cacao trees yielded negative results, and there was no opportunity for inoculating rubber. It is therefore safe to conclude that *C. striispora* is a definite parasite of both Immortelles, but that it probably cannot attack healthy cacao.

A difference has been noted in the relative susceptibility of individual Bocare Immortelle trees to the disease but whether this difference is genetic or physiological could not be determined. It was most marked in the first two trees used for inoculations, one being very difficult to infect and the other very easy. Both have since been attacked naturally but while the 'susceptible' tree succumbed to a severe attack on the trunk, the 'resistant' tree was only attacked on one root and the attack was easily controlled. Of the other eight trees used in the inoculations two appeared to be 'resistant' and the remainder 'susceptible'. They were all about thirty years old.

All inoculations on cacao gave negative results, suggesting that it is strongly resistant. This is confirmed by the observation that naturally occurring diseased trees usually appeared sickly, damaged, old, or cankered.

Age of tree appears to be a factor of considerable importance. While Bocare Immortelles about thirty years old were readily attacked, another plantation of trees ten or twelve years old appeared to be immune in repeated tests. A natural infection was seen on a tree about twenty years old. A good series of Anauca Immortelles was also tested (Table II), the results indicating that young trees show resistance, but that it is possible to infect older ones. The rapid way in which the wounds healed on the younger trees was remarkable.

It was impossible to find strictly comparable Bocare and Anauca Immortelles for comparative resistance trials. All the inoculations however indicated that the Anauca was far more difficult to infect than the Bocare at any age, a result borne out by the field observations.

Climate or season appears to have an important effect on the disease, inoculation being far more difficult in dry weather than in wet. The fact that covering inoculations with watch-glasses containing wet cotton-wool, or irrigating them with water by means of a wick did not markedly increase the percentage success at any season suggests that climate and season are of importance in determining the vigour and resistance of the trees, a conclusion again borne out by field observations.

Series of inoculations in different types of wound at varying depths in different positions on the tree indicated that deep wounds were more successful than shallow wounds, and that the height of the inoculation on the tree was immaterial.

These results are summarised in Table II.

VI. Discussion of Results and Control Measures.

All the experimental work suggests that *C. striispora* can only parasitise trees which are unhealthy or damaged. It is unlikely therefore that the disease will ever be serious on healthy rubber, cacao, or Anauca Immortelles. The case of the Bocare Immortelle is somewhat different as it appears to be much more susceptible.

Which control measure shall be applied depends on the severity of the attack which again depends on the plant attacked and on the environment.

On rubber, for instance, the disease requires no control measures other than the periodic inspection of the trees and the removal of diseased lesions. Wounds caused in this way should be treated with a fungicide or antiseptic to prevent re-infection or the entry of other organisms. Severely attacked trees should be felled and diseased material should be burnt. Although the disease is at present negligible on rubber a close watch must be kept on it as it may become commoner as the trees grow older.

On cacao a slight attack may be dealt with by surgical methods—removal of the diseased lesion with hammer and chisel, followed by the application of a fungicide or antiseptic—and a valuable tree may be saved. Nevertheless, the majority of cacao trees on which attacks were observed appeared to be unhealthy, old or cankered, and could have contributed but little to the yield of the fields in which they stood. Such trees should be removed and if possible burnt and replaced by selected strains. If the disease is at all common it may be taken as an indication either that conditions are too damp for cacao, and black pod and witches' broom disease will be rife, or that the field is in need of replanting.

The control of the disease on the Anauca Immortelle should follow similar lines. Diseased trees are mostly either old or are growing in

Table II.

SUMMARY OF INOCULATIONS.

Series.	Date.	Inoculum.	Tree Inoculated.	Age of Tree (yrs.)	No. of Inoculations.	Percentage Success.
1	19. 7.39	Spores *	Bocare	30	20	0
		Mycelium	Bocare	30	10	0
		Spores and Mycelium	Anauca	20	10	0
2a	20. 9.39	Spores *	Bocare	30	18	0
		Mycelium	Bocare	30	18	0
2b	20. 9.39	Plugs †	Bocare	30	42	14
		Plugs	Anauca	20	6	0
3	15.11.39	Plugs	Bocare	30	66	43
4	20.12.39	Spores *	Bocare	30	24	0
5a	18. 1.40	Spores *	Bocare	30	46	0
5b	18. 1.40	Plugs	Bocare	30	28	50
6	9. 5.40	Plugs	Bocare	30	30	77
7	20. 6.40	Cultures	Bocare	30	36	44
8	4. 7.40	Plugs	Bocare	10	50	0
9a	18. 7.40	Plugs	Bocare	30	10	40
9b	18. 7.40	Ascospores	Bocare	30	40	0
		Conidia	Bocare	30	40	5
10 & 13	1. 8.40 & 3.10.40	Plugs	Anauca	8	10	0
		Plugs	Anauca	10	20	0
		Plugs	Anauca	20	20	10
		Plugs	Anauca	50	15	7·5
11	26. 9.40	Plugs	Cacao	Various	100	0
12	3.10.40	Spores *	Bocare	30	60	0
14	3.10.40	Plugs	Bocare	10	50	0

* Inoculations of Ascospores and Conidia were made separately on all occasions, but where the results of both were negative separate particulars are not given.

† Plugs in all cases were made from diseased Bocare Immortelle bark. No particulars of controls are given. Adequate controls were made for each series and all remained healthy.

unfavourable localities. They should be removed and replaced by young trees of the same species. If young trees are attacked, environmental conditions are obviously unsuitable for the Anauca and must be radically improved. If such an improvement is impossible conditions are probably unsuitable for cacao. If cacao cultivation is to be continued under these conditions an alternative shade tree must be found. It is the writer's opinion that an area where the Anauca was severely attacked would be entirely unsuited to cacao cultivation because black pod and witches' broom disease would take most of the crop, and that such areas should be abandoned. In most areas where cacao can be grown satisfactorily the resistance of the Anauca Immortelle to the disease appears to be satisfactory. The removal of diseased Immortelle trees in cacao fields is best accomplished by poisoning them with sodium arsenate. If this is done the trees tend to fall piecemeal and not to 'crash' all at once. This method is much cheaper than felling and causes less damage to the cacao.

The position of the Bocare Immortelle is not so satisfactory. In Surinam Stahel (9) reported that it was too susceptible to be of any value and that an alternative shade tree would have to be found, and this appears to be the position in the Sangre Grande and Manzanilla areas in Trinidad. Attempts made to control the disease by surgical and sanitary methods have proved unsuccessful and expensive. Lesions are not always easy to eliminate completely when they extend below ground level, and the trees are constantly being reinfected. Furthermore, the large wounds left after the removal of the diseased bark are liable to infection by *Fomes Auberianus* which rapidly causes the death of the tree. Nor does it seem likely that the environmental conditions can be sufficiently improved by drainage or other methods to render the Bocare satisfactorily immune to the disease. It is true that young trees show resistance to the disease, but it is felt that this resistance is insufficient to justify the replanting of large areas with the Bocare Immortelle. It is possible that if a policy were adopted for removing and replacing cacao shade trees at regular intervals, say every twenty or thirty years, the Bocare would have some value, but it is probable that many would succumb to the disease even before they reached the age of thirty years. Until a better shade tree can be found the best policy would probably be to replant areas where Bocare Immortelles have been killed with Anauca Immortelles and to start testing possible alternative shade trees. The Anauca is well known as a successful shade tree for cacao under a variety of conditions and it appears at present to be the best substitute for the Bocare. Plantings of other potential shade trees should only be made in small experimental areas, and as properly planned experiments.

As pointed out by Shephard (8) very large old Immortelle trees constitute a problem on cacao estates even when they are healthy: they are too tall to be really effective as shade, they cannot be felled without considerable expense and damage to the surrounding cacao, and furthermore, they are liable to 'crash' in high winds and thus to cause severe damage to the cacao. It is worth while, therefore, to examine the possibility of removing and replacing cacao shade trees in a definite rotation before they become too large. This is done in Ceylon where the Dadap (*Erythrina lithosperma*) is used for shade, and should be tried in Trinidad with the Anauca Immortelle. A policy of shade replacement over twenty or thirty years might prove exceedingly effective in combating this disease and in preventing damage by falling trees.

VII. Summary.

1. An account is given of a disease of Immortelle trees new to Trinidad. The distribution, host-range and symptoms of the causal fungus *Calostilbe striispora* (Ell. & Ev.) Seaver are discussed.

2. Experimental work was carried out in the field and in the laboratory and a detailed series of inoculations was made to determine the pathogenicity of the fungus on its various hosts under different conditions.

3. Possible control methods including the regular replanting of shade trees are suggested.

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The Editor is prepared to consider signed articles for publication in *Tropical Agriculture*. Such articles should normally vary between 1,000 to 6,000 words and may be illustrated if desired.

EXPERIMENTAL INTERACTIONS.

Statistical science has now taken a firm hold on modern agricultural experimentation. One result has been to overturn some methodological principles that were formerly held to be fundamental to proper experimentation. Of these the chief was the fallacy that it is necessary to ask only one question at a time, and that every experiment must be so planned and simplified that there is only one variate to be measured. This principle still holds good in experimentation where the variates can logically be isolated (as in some physical experiments). It is, however, unsound in biological experiments of every kind.

The unsoundness of considering single variates or factors in biological work arises from the fact that in an organism or complex of organisms no factor can be varied without introducing variation in other factors or constituents of the organisms; furthermore, no plant can be considered as isolated from its environment. As an example, a one-element fertilizer given to a plant will affect its growth in some way; if the plant grows bigger, its needs for carbon dioxide, for water and for additional fertilizer elements will also increase—up to a point when developmental changes set in that may reduce the need for materials previously required. As regards the effect of the medium or environment, it is clear that no general manurial experiment can be undertaken which does not take account of varieties of the plant tested, while any varietal trial will also be conditioned by the nature and amounts of the fertilizer supplied.

The outmoded "classical" system of attempting to isolate variates which are essentially interlinked succeeded in producing results which were valid only for the particular conditions chosen. The results were thus deprived of much, if not of practically all, validity in application. Even if the statistical significance of the average of a large number of trials of the effect of a particular fertilizer be granted for any one species, the result does not help in determining the extent of interaction of that fertilizer with any other. An estimate of interaction is *a priori* excluded.

It is the special merit of R. A. Fisher's technique of randomization and factorial experimentation that not merely the effects of single factors are estimated with a precision at least equal to that afforded by the "classical" method, but that the effects of any desired interactions are assessed at the same time as the effects of the main factors, and with the same precision. The randomization technique and the statistical analysis of the results springing from it give us opportunities for obtaining information which classical experimentation supplied much less efficiently, if at all.

Interactions have been studied at Rothamsted for a number of years. The first reference to fertilizer interactions occurs in the Annual Report for 1929, but it was not until about 1931 that the study of interactions became thoroughly established. A good example of the application of the study of interactions to a commercial crop is the series of trials with sugar beet at 30 centres on six types of soil, reported on pp. 175-196 of the Report for 1937. At each centre the main effects and interactions of three levels of each of the three nutrients, N, P and K were tested. There was a significant positive interaction in total sugar between sulphate of ammonia and muriate of potash on the average of all centres, though at only two centres were there individually significant positive interactions. An example easier to survey is that reported on p. 216 of the same Report. On fen soil manganese sulphate given at two levels produced significant increases in total sugar of sugar beet at both levels; a dose of nitrate of soda produced small but not significant increases when manganese sulphate was given, but nitrate gave no increase in root tops, or total sugar in the absence of manganese. It is clear that we cannot here speak of the effect of nitrate unless we specify whether manganese was given or withheld.

Recent developments in the theory of experimentation, as applied in R. A. Fisher's technique of "confounding" and F. Yate's newer "partial confounding", have made it possible to study chosen interactions of high order, or involving a large number of factors, with a considerable economy of plots or pots. The practice of "confounding" throws away some information about any predetermined set of interactions, but preserves full accuracy regarding the main effects and the other interactions.

There is thus a very efficient and effective technique for studying interactions. It is probably on account of the difficulty and laboriousness of applying the older methods of experimentation to interactions that the study of interactions has not everywhere received the attention it deserves. Fisher's technique is, however, becoming better known, and preoccupation with single factors is coming to be regarded as old-fashioned. There is evidence that the scientific value of studying factors one at a time is being questioned. In a recent series of papers O. de Vries of Groningen has examined the yield factor *c* in Mitscherlich's law of constant nutrient effect, and has shown that this factor is not a constant. When the fertility level rises, *c* may decrease; but it is shown by de Vries that in other cases *c* increases, so that maximal yield is obtained at lower values of the growth factor in question. In the first case the growth factors are additive and must supplement each other; in the second case, there is compensation between them. Mitscherlich's case (*c* a constant) takes the zero or transitional position between these two. That the "law" does not generally hold is what may be expected, since it is an attempt at a static representation of a dynamic variation, *c* being a variate or set of variates that is itself subject to variation through interactions which the "law" does not attempt to define.—(*Soils and Fertilizers*, Vol. III, No. 3.)

REVIEW.

AGRICULTURE IN UGANDA.

By the Staff of the Department of Agriculture, Uganda; edited by J. D. Tothill, C.M.G., D.SC. Oxford University Press, London: Humphrey Milford, 1940, pp. 537, price 20*s*.

"Agriculture in Uganda" which has been compiled by the members of the Staff of the Uganda Department of Agriculture and edited by Dr. Tothill, the former Director of Agriculture, provides a quite up-to-date record. The first few chapters deal generally with the topography and climate of the country and aspects of native agriculture such as land tenure, rotation of crops, ploughing, soil erosion and manuring, with a short section in which are described the various experimental stations established in the country. Uganda is a native protectorate and by far the vast majority of the population is dependent on some form of agriculture for a livelihood or for subsistence. There is some small development of "European" or settler agriculture, but these enterprises are restricted to a few economic crops requiring capital investment—such as sugar milling and, to a lesser extent, tea, rubber and coffee planting. The volume, therefore, is largely and rightly a record of native agriculture, its practice, extent and improvement. Perusal of the table of contents reveals what diverse crops are grown, and equally what diverse pests infests them.

Native food crops are well treated and in sections 4, 5, 6 and 7 bananas, root crops, cereals, oil seeds and pulses are dealt with. As was to be expected, section 8 dealing with cotton is extensive and particularly well done. This crop has received special attention over a long period and is the main economic crop produced by the Protectorate, accounting for well over half of the total value of the country's annual export. The undesirability of such dominance of the country's economy by one crop is well understood and it is clear from the book that steady and unceasing attention is being paid to crops in other categories. At the same time there is an increasing endeavour to remove many of the risks connected with cotton growing; the country has to be kept going, and cotton is likely to remain the king of crops there.

It will be noted that there has been a steadily improving and more effective treatment of the problems of marketing, so that the primitive systems which took little account of quality and condition of produce are gradually being displaced by an orderly approach to the handling of the increasing tonnages of surplus of every description leaving the country. Grading and inspection is becoming more generally applied, and the system of outright purchase for cash at time of sale is displacing the old barter system in the marketing of at least the export commodities.

Attention is drawn to the record of the vicissitudes of many crops. The history of tea, tobacco and especially coffee is revealing and of interest. None reading the sections devoted to these crops can fail to realise the continual difficulties which beset pioneers in new crops, not from the economic aspect alone, but culturally. Here surely is a warning to those whose idea of developing a crop is merely to grow it on a steadily increasing scale; numberless situations arise or herald their approach which cumulatively may make the prospects gloomy indeed.

That the agriculturist in Uganda has not lacked enterprise is clear from the experimental and commercial attempts to increase the numbers of crops which may add to the country's resources, and diversify its output of commodities.

Perhaps the most fruitful and provocative endeavour is connected with the development of a native agricultural system which embraces the utility and development of stock keeping as part of a well designed whole. The "small holding" project, and all the record and experimental work connected therewith appears to be the natural outcome of experience gained throughout the past thirty years, and the projects, if guided soundly, and permitted to develop at the pace of development of the average cultivator, and especially without burdensome capital advances, should do much to meet the growing demand for an improved standard of living, and at the same time advance the standard of agricultural practice.

Finally there is a section on agricultural education and extension work. The need for bringing the results of trials on crops to the people and of demonstrating improving agricultural systems was early recognised in Uganda, and a natural development was the establishment of a long term course in agricultural education and training at the College at Makerere.

Whilst it is not denied that there is some unbalance in agricultural work in Uganda (and where is there none), this volume is a timely contribution showing at least that the Government has long been alive to, and apprehensive of the needs of the people, and that a considerable fund of information based on reality and experience is available for the use of the agriculturist there. Nor is its utility confined to Uganda; much of what appears is at least a guide to workers in other colonies; in many cases it gives direct help, and may be confidently used.

The Editor requests that any subscriber who fails to receive *Tropical Agriculture* regularly should communicate with him immediately in order that the matter may be rectified.

CHEMICAL NOTES.

(Compiled by the College Department of Chemistry and Soil Science.)

Nitrogenous Manuring of Sugar Cane in South Africa.

H. H. Dodds and J. E. Colepepper, in the *Proceedings of the 14th Annual Congress South African Sugar Technol. Association*, 1940, note that doubt has been raised in South Africa about the prime necessity for nitrogen in sugar-cane cultivation. This paper reviews what has been done on the subject, from which four principal conclusions have been drawn, as follows:—

(1) The supply of moisture, which is sometimes very deficient for sugar cane and may remain so over a cycle of years, is often a limiting factor and may seriously interfere with the response of the cane to fertilizer treatment. In such periods there seems to be some evidence that sugar cane may respond to gradually available organic nitrogen such as in whale guano, and not to the immediately soluble and rapidly available inorganic forms such as ammonium sulphate and sodium nitrate.

(2) With an adequate moisture supply, ammonium sulphate seems to be the most economical artificial nitrogenous fertilizer to apply, usually in quantities of 400 lb. per acre, applied in one or more dressings, if possible during rainy weather, and in the case of plant-cane not applied until the cane is well established and at least several inches high. The latter is more particularly the case in light sandy soils; too early application may impair germination, especially with deficient moisture.

(3) There is some evidence that a greater response may be expected with Co.301 than with either Co.281 or Co.290 under conditions that have prevailed over the past season or two. No information on this point is yet available concerning the other varieties now also extensively under cultivation, mainly Uba and P.O.J.2725.

(4) It may be that, as in some other cane growing countries, the cultivation of a leguminous green manure crop before planting with cane may serve to supply, wholly or in part, the nitrogen requirements of the plant-cane crop.—(*Facts about Sugar*, 1940, Vol. XXXV, No. 10, p. 33.)

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Alcohol for Cellulosic Materials.

M. Giordani, in *Chemicae Industria*, Vol. XXI, No. 5, p. 265, describes the Giordani-Leone process of preparing alcohol from wood, straw, bagasse, or other materials containing cellulose; this process is a modification of the Bergius process. The fabricative operations are as follows:—The cellulosic material, without special preparation, is first heated in an autoclave for 30 minutes at 150°C. with very dilute sulphuric acid; this acid extract is passed through a distilling column where more than 20 kilograms of furfural per ton of dry material is recovered. The residual liquor from this column (solution A) contains about four per cent. of reducing sugars and is used later in the process. The solid residue of cellulose and lignin from the autoclave, which contains 35 to 40 per cent. of the acid solution, is pressed and dried until its moisture content is about eight per cent. It is then triturated in a power mixer with sulphuric acid of not above 60° Baumé; the proportion of acid used depends on the kind of cellulosic material that is being treated. The black paste is diluted with solution A and boiled for about 30 minutes to complete the hydrolysis. After neutralization with calcium carbonate and filtering, a wort is obtained that has about 12 per cent. of reducing sugars. The wort thus prepared is fermented with a yeast that has been specially acclimatised to this medium. The yields of products per metric ton of fir wood are given as 300 liters of anhydrous alcohol, 20 kilograms of furfural, 2 kilograms of acetic acid, and 300 kilograms of dry lignin. The spent liquor from the alcoholic fermentation still contains 120 kilograms of reducing sugars not fermentable by yeasts, but which can be fermented by bacteria, such as *Clostridium acetobutylicum*, which produce various organic products. A factory with a capacity of 18,000 liters of anhydrous alcohol a day is being erected at Bolzano to work the Giordani-Leone process and will begin operations in October, 1940.—(*Facts about Sugar*, 1940, Vol. XXXV, No. 10, p. 37.)

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The Caking of Fertilizers.—*J. Richard Adams and William H. Ross.**

The caking of fertilizers results as a rule from the knitting together of the crystals of which the material or mixture is composed. This knitting together of crystals may occur when a material undergoes a change in crystal form, when a material crystallizes from the solution phase, when new crystals are formed as a result of chemical reaction between the components of a mixture, and when a material combines with the free water present to form a soluble or insoluble hydrated compound. Ordinary changes in temperature and pressure may influence the rate of setting of water-insoluble hydrates, but these factors have little or no effect on the ultimate hardness of the caked mass. The caking of water-soluble materials by crystallization differs from that which accompanies the formation of insoluble hydrates in that, not only the rate, but also the extent of caking may be markedly affected by relatively small changes in temperature and pressure. The rate and extent to which caking takes place in a fertilizer mixture of the ordinary type will vary with the moisture content, the size of the particles, the applied pressure under which it is stored, the temperature changes during storage, and the time of storage. Data are presented showing the effect of these factors on the relative caking tendencies of different fertilizer materials and mixtures—(*Journ. Soc. Chem. Indus.*, 1940, Vol. 59, No. 39, p. 678).

**Division of Fertilizer Research, Bureau of Plant Industry, Washington, D.C.*